SOVIET PHYSICS – DOKLADY VOL. 16, NO. 5 NOVEMBER, 1971

PHYSICS

FERMI SURFACE OF ARSENIC UNDER PRESSURE

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Translated from Doklady Akademii Nauk SSSR, Vol. 198, No. 3, pp. 563-564, May, 1971
Original article submitted September 28, 1970

High-pressure techniques have proved extremely useful in the experimental study of the electron properties of metals.

In this paper we shall describe the first study ever of giant quantum oscillations (as well as ordinary quantum oscillations) of the absorption of ultrasonic waves in arsenic at various pressures. The giant quantum oscillations in arsenic are realized in the narrow γ necks of the hole-type Fermi surface proposed by P. Lin and L. Falicov [1] (Fig. 1).

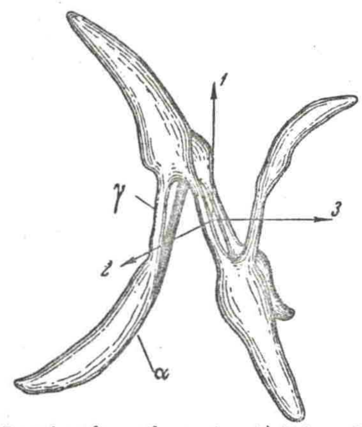

Fig. 1. Hole Fermi surface of arsenic. 1) Trigonal; 2) binary; 3) bisector axis.

A sharp change in the topology of the narrow necks may reasonably be expected under the influence of high pressures.

Longitudinal ultrasound at a frequency of f = 200 MHz was directed along the trigonal axis of 99.999% pure arsenic single crystals. The direction of the magnetic field **H** coincided with the wave vector **q**. For measuring the sound absorption coefficient at 1.6°K we used the ultrasonic pulse method, obtaining the high pressure by the technique described earlier [2]. At low temperatures the pressure was measured with a superconducting indium manometer, using existing data relating to the destruction of superconductivity by a magnetic field [3]. The reproducibility of the results was verified for a number of samples by carrying out successive measurements at zero, finite, and zero pressures.

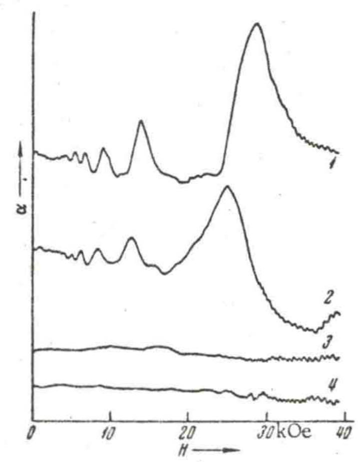

Fig. 2. Sound absorption coefficient α in a magnetic field at a pressure of: 1) 0; 2) 2 kbars; 3) 4 kbars; 4) 6 kbars.

The oscillatory character of the sound absorption coefficient in magnetic fields and the relation between the periods of the observed oscillations and the pressure are illustrated in Figs. 2 and 3 respectively.

The quantum oscillations of ultrasound absorption (Fig. 2) in the magnetic-field range 30-40

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kOe correspond to the extremal sections of the α parts of the Fermi surface, transverse to the field H. The value of the period $\Delta_\alpha(H^{-1}) = 5.33 \cdot 10^{-7}$ Oe^{-1} coincides with the value given earlier [4, 5] and remains constant to within $\pm$ 3% up to a pressure of 6 kbars.

The giant quantum oscillations corresponding to the extremal area of the γ necks of the hole surface, transverse to the field H, give a period of $\Delta_\gamma(H^{-1}) = 3.71 \cdot 10^{-5}$ Oe^{-1} at zero pressure, this remaining almost constant (to within $\pm$3%) up to a pressure of 2 kbars. For a pressure of the order of 2.5 kbars, the strict periodicity of the giant quantum oscillations with respect to the reciprocal field was disrupted, and this impeded calculation of the period. An estimate of this period indicates a reduction of approximately 15% in the cross-sectional area. For a pressure of about 3 kbars the giant quantum oscillations vanish; this may be interpreted as the disruption of the γ necks connecting the α parts of the hole Fermi surface, i.e., as a higher-order phase transformation, such as that considered earlier [6].

As indicated by S. Golin [7], the presence of hole necks on the Fermi surface of arsenic is associated with the degeneracy of the band structure. This degeneracy may be removed by spin-orbital interaction. While the energy of the spin-orbital splitting $\lambda \ll 2(E - E_F)$, where E is the degeneracy energy and E_F is the Fermi energy, the hole Fermi surface retains the form illustrated in Fig. 1. However, when the spin-orbital splitting becomes sufficient to satisfy the condition $\lambda < 2(E_0 - E_F)$, the hole γ necks vanish, as indeed we observed experimentally by virtue of the vanishing of the giant quantum oscillations at pressures of over 3 kbars.

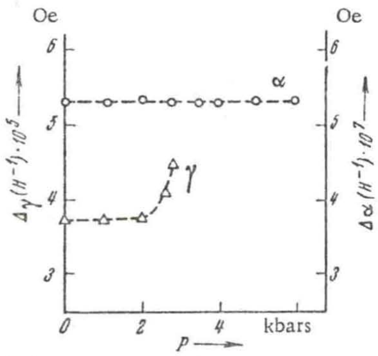

Fig. 3. Oscillation periods of the sound absorption coefficient in relation to the pressure.

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